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(54) **Fabrication of ink feed slots in a silicon substrate of a thermal ink jet printer**

Herstellung von Tintenzufuhrkanälen in einem Siliziumsubstrat eines Thermotintenstrahl Druckers

Fabrication de fentes d'alimentation dans un substrat silicium pour une imprimante thermique à jet d'encre

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US-A- 5 308 442 **US-A- 5 387 314**

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Description

[0001] The present invention relates to thermal ink-jet printheads, more particularly to an improved procedure for making ink feed slots in a silicon substrate used in the construction of thermal ink-jet printheads.

Background

[0002] Thermal ink-jet printheads typically incorporate a plurality of electrical resistance elements on a common substrate for the purpose of heating ink in adjacent reservoirs in order to vaporize a component of the ink composition. The vaporized component of the ink composition imparts mechanical energy to a quantity of ink thereby propelling the ink through one or more orifices in an orifice plate of the ink-jet printhead toward a print medium in a predefined sequence to form alphanumeric characters and graphics thereon.

[0003] In order to provide better print quality, many electrical resistance elements and orifices are provided on a single ink-jet printhead. As the number of electrical resistance elements and orifices on the printhead increases so does the print quality. However, increasing the number of electrical resistance elements and orifices on a single ink-jet printhead also increases the manufacturing difficulties associated with alignment tolerances of photomasks which must be maintained during fabrication in order to etch the substrate in the desired manner.

[0004] On a micro-scale, the ink-jet printhead must be precisely manufactured so that the components of the printhead cooperate to achieve the desired function and give the desired print quality. Hence, alignment of the ink feed slots, electrical resistance elements and orifices is critical to the proper operation of the ink-jet print head. The ink feed slots provide ink from a reservoir to the electrical resistance elements during the printing process. Since the printheads are precise micro-structural devices, even minor deviations or manufacturing difficulties during production of the ink-jet printhead components may result in a loss of useable substrate material and thus a low product yield.

[0005] One of the manufacturing techniques used for forming ink feed slots in a silicon substrate of a thermal ink-jet printhead is an anisotropic etching technique. In this process, a silicon wafer having parallel (100) crystallographic planes is anisotropically etched to produce an elongated slot having a length ranging from about 3 to about 5 mm, a width ranging from about 0.5 to 2 mm and side walls which are at an angle of about 54.7° from the planar surface of the silicon wafer. Prior to completion of the printhead, electrical resistance elements and electrodes are attached to one surface of the silicon substrate adjacent the ink feed slots. Manufacturing difficulties are often encountered when attempting to precisely position the feed slots and electrical resistance elements relative to one another.

[0006] U.S. Patent No. 5,387,314 to Baughman et al. discloses a method for making ink fill slots in a silicon substrate. The disclosed procedure includes a partial anisotropic etch from one surface of the silicon substrate whereby the fill slots are etched only part way through the substrate. In a subsequent step, an isotropic etchant is used to complete the fill slots from the opposing surface of the substrate. According to Baughman et al., isotropically etching the silicon from the opposing surface of the substrate reduces the distance from the ink fill slot to the entrance of the ink feed channel. While the method Baughman et al. may reduce the effect of alignment problems in the manufacture of ink fill slots relative to the electrical resistance elements, it requires that the fill slots be extended to the firing chamber on the opposing surface of the substrate by use of a subsequent masking and isotropic etching step. Thus, the procedure requires a combination of etching procedures with multiple alignment of photo-masks which may make the manufacturing of the ink-jet printheads more difficult, costly and subject to alignment errors.

[0007] U.S. Patent No. 5,308,442 to Taub et al. relates to another method for making printhead structures for introducing ink into the firing chambers of the printhead. In this process, a fragile membrane layer having a thickness of about 1 to 2 microns of dielectric material covers an etched ink fill slot until the resistors are formed and then the membrane is removed. As with many other manufacturing processes, the substrate having a membrane covering the ink fill slot must be handled with extreme care in order to avoid puncturing the membrane before the resistors are formed on the surface of the substrate. At high production rates, the yield of product using this technique may be unacceptably low.

[0008] U.S. Patent No. 4,789,425 to Drake et al. relates to yet another method for fabricating thermal ink-jet printheads. The method disclosed by Drake et al. requires the use of etched alignment holes for use in patterning the silicon substrate for the fill slot etching process and for locating the position of the electrical resistance elements on the circuit side of the silicon substrate.

[0009] In the disclosed procedure, Drake et al. first patterns then partially or completely anisotropically etches the alignment holes and partially etches the reservoir/fill slots in the substrate. After partially etching the reservoir/fill slots, the resistance circuits are formed on the wafer. In another embodiment, Drake et al. completely etches the alignment holes through the substrate, the resistance circuits are formed then passivated, and the reservoir/fill slots are then patterned and etched in the substrate. Accordingly, Drake et al. require several critical aligning and patterning steps for locating the alignment holes, reservoir/fill slots and electrical resistance elements.

[0010] Since alignment steps are often performed manually, the use of multiple alignment steps adds to the labor costs, increases failure rate and slows down the production rate of the etched substrate parts. As the

print speed and print quality of the ink-jet printers is increased, the fabrication tolerances become even more critical making the use of multiple masking and etching steps even less reliable for locating the position of the reservoir/feed slots and electrical resistance elements.

[0011] An object of the present invention is to provide an improved method for making ink feed slots for ink-jet printheads.

[0012] Another object of the invention is to improve the fabrication technique for forming ink feed slots for use in ink-jet printheads whereby the yield of acceptable product is increased.

[0013] A still further object of the invention is to provide an improved method for increasing the accuracy of locating electrical resistance elements relative to the ink feed slots of an thermal ink-jet printhead.

[0014] Another object of the invention is to reduce alignment difficulties and process steps thereby decreasing the time and increasing the yield of useable substrates for thermal ink-jet printheads.

Summary of the Invention

[0015] The invention provides a method for fabricating a topshooter type thermal ink-jet printhead for use in an ink-jet printing device. In the initial step of the process, a plurality of alignment holes are drilled through an oxidized silicon wafer substrate using a laser beam, each hole having an entry on a first surface of the substrate with a diameter of from about 5 to about 100 microns, preferably about 50 microns, and an exit on a second surface of the substrate having a diameter of from about 5 to about 50 microns, preferably about 25 microns.

[0016] One or more layers, each of which may contain arrays of resistive material, conductive material, insulative material or a combination of resistive, conductive and insulative materials, are deposited and patterned on the second oxidized surface of the substrate using the drilled alignment holes for alignment and patterning of the one or more layers. The conductive materials may contain a plurality of electrodes formed from metal such as Al or Cu for contacting and energizing the heating elements. In order to protect the layers of resistive, conductive and insulative materials during the etching steps, these layers are passivated with one or more passivation layers selected from SiO_2 , Si_3N_4 , SiC or other suitable passivation material. A tantalum layer may then be deposited on the one or more passivation layers and the entire second surface is coated with a protective blanket layer or passivation layer to protect the devices against etchants used to etch the feed slots. The protective blanket layer may be selected from SiN , SiC , SiO_2 or any other suitable material known in the art.

[0017] After depositing the protective blanket layer on the one or more passivation layers and tantalum layer on the second surface, a plurality of elongate marks are patterned in the oxidized layer on the first surface of the

substrate using the alignment holes to define the position of the marks. The first surface is then anisotropically etched according to the pre-defined pattern of elongate marks thereby producing a plurality of elongate ink feed slots which terminate at the oxidized layer on the second surface of the substrate. After completing the feed slot etching process, the protective blanket layer and oxidized layer on the second surface may be removed by wet or dry etch techniques or other techniques known to those in the art.

[0018] An advantage of the invention is the elimination of the patterning and etch steps required for forming alignment holes in the silicon substrate. Furthermore, the laser drilled alignment holes may be more carefully controlled and sized as compared to etching techniques for the alignment holes. Since the alignment holes may be made more precisely, location of the resistive elements and ink feed slots relative to the alignment holes is easier. An increase in yield of useable product is expected by use of this fabrication procedure.

[0019] A particular advantage of the method is that the feed slot may be etched through the substrate in one anisotropic etching step using only one alignment step. Since at least one masking and aligning step is eliminated, the yield of usable product is expected to be relatively higher than the yield from techniques requiring multiple masking and alignment steps.

Brief Description of the Drawings

[0020] Further objects and advantages of the invention, and the manner of their implementation, will become apparent upon reading the following detailed description with reference to the drawings in which like reference numerals denote like elements throughout the drawings and wherein:

[0021] Fig. 1A is an enlarged schematic plan view, not to scale, of a silicon wafer substrate containing a plurality of heating element substrates and a predetermined number of substrates containing an alignment hole according to the invention.

[0022] Fig. 1B is an enlarged schematic plan view, not to scale, of one of the substrates of Fig. 1A containing an alignment hole.

[0023] Fig. 1C is an enlarged schematic plan view, not to scale, of one of the heating element substrates of Fig. 1A.

[0024] Figs. 2A-G are cross-sectional views, not to scale, of a portions of the silicon wafer depicting an alternative process for producing ink feed slots in a heating element substrate.

Detailed Description

[0025] In Fig. 1A-1C, shows a fully processed silicon wafer 34, containing a plurality of alignment hole sections 36 containing one or more alignment holes 38 and a plurality of ink-jet printhead structures 40 having an

ink feed slot 20, adjacent heating elements 24, energizing electrodes 28, energizing electrode terminals 42, common return circuit 30, and common return terminals 44.

[0026] Now with reference to Figs. 2A-2G, the fabrication procedure for the embodiment of Figs. 1A-1C of the invention is illustrated. In Fig. 2A, a silicon wafer substrate having mask layer 8 (e.g. Si_3N_4) and dielectric layer 10 (e.g. SiO_2) has a photoresist layer 14 deposited on the mask layer 8 on the first surface 4 of the substrate. The photoresist layer has a thickness of about 1 to about 2 microns. Next, a plurality of alignment holes 38, preferably at least about three or more, are drilled at spatially separate locations in the silicon wafer substrate 34 (Fig. 1A) using a laser beam. The holes are preferably drilled around the periphery of the wafer in an area of the wafer that is remote from sections which may be used in the printheads.

[0027] Any suitable laser beam source may be used to drill the holes. A preferred laser beam source is a Q-Switched YAG laser. Another preferred laser beam source is an aligned-optics two beam excimer laser. Lasers having sufficient power for drilling holes in the substrate include models MEL-40 and LMS having 8 to 50 watts of power which are commercially available from Florod of Gardena, California. Lumonics of Camarillo, California may also provide suitable lasers for drilling the substrate.

[0028] The laser drilled holes 38 preferably have an entry 46 on the first surface 4 of the silicon substrate of from about 5 to about 100 microns, preferably about 50 microns and an exit 48 on the second surface 6 of the silicon substrate 2 having a diameter of from about 5 to about 50 microns, preferably about 25 microns. Larger or smaller alignment holes may be drilled in the silicon substrate, however for ease of alignment, the foregoing entry and exit hole sizes are preferred.

[0029] When using a Q-switched YAG laser, the entry hole 46 will often be larger than the exit hole 48 with a 25 micron hole being about the smallest hole which may be cut using the YAG laser. However, the smaller the hole the greater the accuracy of alignment which can be obtained, provided the hole is large enough to be visible to the aligner.

[0030] One or more layers of resistive material 24 may then be deposited and patterned on the dielectric layer 10 using the alignment holes 38 to determine the position for depositing and patterning the resistive material 24 as illustrated in Fig. 2B. The layers of resistive material 24 are used as the heating elements for vaporizing an ink component and will generally have a thickness of about 1000 Å. Resistive material which may be used includes doped polycrystalline silicon which may be deposited by chemical vapor deposition (CVD) or any other well known resistive material such as HfB_2 or TaAl.

[0031] The heating elements 24 are energized by a plurality of electrodes 28 and 30 formed from one or more conductive layers deposited on the dielectric layer

10 in contact with the resistive material 24 for conduction of electrical pulses to the individual heating elements (Fig. 2C). Electrodes 28 and 30 may be formed from vapor deposited aluminum or sputtered Al/Cu alloy and will typically have a thickness of about 5000 Å.

[0032] In order to protect the resistive material 24 and electrodes 28 and 30 during subsequent processing steps, it is preferred to deposit a blanket protective coating 26 over the resistive material 24 and electrodes 28 and 30 on the dielectric layer 10. The protective coating may be deposited or grown using any of the well known chemical vapor deposition techniques. Suitable protective coatings include Si_3N_4 , SiO_2 , SiC and the like with the preferred being Si_3N_4 and SiC. The total thickness of the protective coating is preferably about 5000 Å.

[0033] Subsequent to protectively coating the resistive material 24 and electrodes 28 and 30, select portions of the photoresist layer 14 are patterned and developed thereby exposing a portion 16 of the mask layer 8 (Fig. 2D). The positioning of the photoresist mask used to expose the portion 16 of the mask layer 8 is determined by reference to the previously drilled alignment holes 38. The exposed portion 16 of the mask layer 8 may then be etched away using a plasma or wet-etch process such as a buffered hydrofluoric acid solution thereby forming a plurality of elongate marks 18 in the mask layer 8. After forming the elongate marks 18, the photoresist layer 14 is removed by means of acids, organic solvents such as acetone or chemical combustion in an oxygen glow discharge chamber (Fig. 2E).

[0034] Once the elongate marks 18 are formed in the mask layer 8, the silicon substrate 2 is anisotropic etched from the planar (100) crystallographic surface 4 to form a plurality of elongate ink feed slots 20 (Fig. 2F). Any known anisotropic etchant may be used. The preferred anisotropic etchants may be selected from an aqueous alkaline solution and an aqueous mixture of phenol and amine. Of the aqueous alkaline solutions, a potassium hydroxide solution is the most preferred. Other anisotropic etchants include sodium hydroxide, a mixture of hydrazine and tetramethyl ammonium hydroxide and a mixture of pyrocatechol and ethylene diamine.

[0035] Since processing of the second surface of the silicon substrate is substantially complete prior to the anisotropic etching step, the etching step may be conducted until the feed slot 20 reaches the dielectric layer 10 on the second surface 6 of the substrate 2.

[0036] In order to complete the fabrication of the printhead structure, the protective coating 26 over the resistive, conductive and insulative materials is removed by reactive ion etching (RIE) techniques until the Ta over the resistive material and the Al on the conductive material is exposed. At this point, there still remains a thin layer of protective material 26 and dielectric layer 10 over the feed slot 20 which may be removed by abrasion, laser ablation, air blast, water blast or any other well known technique. The completed elongate feed slot 20 is illustrated in figure 2G.

[0037] Using the foregoing method, at least one of the photoresist masking and developing steps is eliminated as compared to conventional processing techniques. Since each time the photoresist layer is formed, developed and the etch masks used, there is an opportunity for alignment errors, elimination of at least one of the photoresist masking steps should result in a substantial increase in yield of useable printhead chips.

[0038] Completion of the printhead structures described in the foregoing process, including forming the nozzles structures above the resistive, conductive and insulative materials may be conducted using conventional processing techniques.

Claims

1. A method for fabricating a topshooter type thermal ink-jet printhead for use in an ink-jet printing device, comprising the steps of:

drilling a plurality of alignment holes through a silicon wafer substrate having oxidized layers on the first and second surfaces using a laser beam, each hole having an entry on a first surface of the substrate having a diameter of from about 5 to about 100 microns and an exit on a second surface of the substrate having a diameter of from about 5 to about 50 microns;

depositing one or more layers of resistive material, conductive material and insulative material on the oxidized second surface of the substrate using the alignment holes for aligning and patterning the resistive, conductive and insulative materials;

passivating the resistive, conductive and insulative materials on the second surface of the substrate with one or more passivation layers;

coating the passivated surface with a protective blanket layer;

coating the first oxidized surface with a mask layer;

patterning a plurality of elongate marks on the oxidized first surface of the substrate using the alignment holes to pattern the marks;

anisotropically etching the substrate according to the patterned marks in the first surface thereby producing a plurality of elongate slots from the first surface to the second surface which terminate at the oxidized layer on the second surface;

removing the protective blanket layer and oxidized layer on the second surface thereby completing the elongate feed slots from the first surface to the second surface of the substrate.

2. The method of claim 1 wherein the anisotropic etchant is selected from an aqueous alkaline solution

and an aqueous mixture of a phenol and an amine.

3. The method of claim 1 wherein the entry on the first surface is about 50 microns in diameter.

4. The method of claim 1 wherein the exit on the second surface is about 25 microns in diameter.

10 Patentansprüche

1. Verfahren zur Fertigung eines Tintenstrahlthermodruckkopfs vom Kopfausschleudertyp zur Verwendung in einer Tintenstrahl Druckvorrichtung, umfassend die Schritte:

Bohren einer Mehrzahl von Ausrichtlöchern durch ein Siliciumwafersubstrat mit Oxidschichten auf der ersten und zweiten Oberfläche unter Verwendung eines Laserstrahls, wobei jedes Loch auf einer ersten Oberfläche des Substrats eine Eintrittsöffnung mit einem Durchmesser von etwa 5 bis etwa 100 Mikrometern und auf einer zweiten Oberfläche des Substrats eine Austrittsöffnung mit einem Durchmesser von etwa 5 bis etwa 50 Mikrometern aufweist;

Aufbringen von einer oder mehreren Schichten von widerstandsbehaftetem Material, leitfähigem Material und isolierendem Material auf der oxidierten zweiten Oberfläche des Substrats, wobei die Ausrichtlöcher verwendet werden, um die widerstandsbehafteten, leitfähigen und isolierenden Materialien auszurichten und zu Mustern zu bilden;

Passivieren der widerstandsbehafteten, leitfähigen und isolierenden Materialien auf der zweiten Oberfläche des Substrats mit einer oder mehreren Passivierungsschichten;

Überziehen der passivierten Oberfläche mit einer schützenden Deckschicht;

Überziehen der ersten oxidierten Oberfläche mit einer Maskenschicht;

Bilden einer Mehrzahl von langgestreckten Markierungen auf der oxidierten ersten Oberfläche des Substrats zu Mustern, wobei die Ausrichtlöcher benutzt werden, um die Markierungen zu Mustern zu bilden;

anisotropes Ätzen des Substrats entsprechend den zu Mustern gebildeten Markierungen in der ersten Oberfläche, wodurch eine Mehrzahl von langgestreckten Schlitzten von der ersten Oberfläche aus bis zur zweiten Oberfläche erzeugt wird, die an der Oxidschicht der zweiten Oberfläche enden;

Entfernen der schützenden Deckschicht und Oxidschicht auf der zweiten Oberfläche, wodurch die langgestreckten Zufuhrschlitze von

der ersten Oberfläche bis zur zweiten Oberfläche des Substrats vervollständigt werden.

2. Verfahren nach Anspruch 1, bei dem das anisotropes Ätzmittel aus einer wäßrigen Alkalilösung und einer wäßrigen Mischung von einem Phenol und einem Amin ausgewählt ist. 5
3. Verfahren nach Anspruch 1, bei dem die Eintrittsöffnung auf der ersten Oberfläche etwa 50 Mikrometer im Durchmesser beträgt. 10
4. Verfahren nach Anspruch 1, bei dem die Austrittsöffnung auf der zweiten Oberfläche etwa 25 Mikrometer im Durchmesser beträgt. 15

Revendications

1. Procédé de fabrication d'une tête d'impression thermique à jet d'encre du type à frappe supérieure, destinée à un dispositif d'impression à jet d'encre, comprenant les étapes de : 20
 - perçage, au moyen d'un faisceau laser, d'une pluralité de trous d'alignement à travers un substrat, consistant en une plaquette de silicium comportant des couches oxydées sur les première et seconde surfaces, chaque trou présentant, dans une première surface du substrat, une entrée ayant un diamètre compris entre environ 5 et environ 100 microns, et une sortie, située dans une seconde surface du substrat et ayant un diamètre compris entre environ 5 et environ 50 microns ; 25
 - dépôt d'une ou de plusieurs couches de matière résistive, de matière conductrice et de matière isolante, sur la seconde surface oxydée du substrat, en utilisant les trous d'alignement pour procéder à l'alignement et à la formation de motifs des matières résistive, conductrice et isolante ; 30
 - passivation des matières résistive, conductrice et isolante sur la seconde surface du substrat, par une ou plusieurs couche(s) de passivation ; 35
 - revêtement de la surface passivée par une couche de recouvrement protecteur ; 40
 - revêtement de la première surface oxydée par une couche de masquage ; 45
 - formation d'une pluralité de repères allongés sur la première surface oxydée du substrat, au moyen des trous d'alignement pour former le motif des repères ; 50
 - attaque anisotropique du substrat en fonction des repères formés dans la première surface, pour ainsi produire une pluralité de fentes allongées partant de la première surface jusqu'à la seconde surface et se terminant au niveau 55

de la couche oxydée sur la seconde surface du substrat ;

élimination de la couche de recouvrement protecteur et de la couche oxydée, sur la seconde surface, pour ainsi parachever les fentes allongées d'aménée allant de la première surface jusqu'à la seconde surface du substrat.

2. Procédé selon la revendication 1, dans lequel le réactif d'attaque anisotropique est sélectionné parmi une solution alcaline aqueuse et un mélange aqueux d'un phénol et d'une amine. 10
3. Procédé selon la revendication 1, dans lequel l'entrée, dans la première surface, a un diamètre d'environ 50 microns. 15
4. Procédé selon la revendication 1, dans lequel la sortie, dans la seconde surface, a un diamètre d'environ 25 microns. 20

Fig. 1A

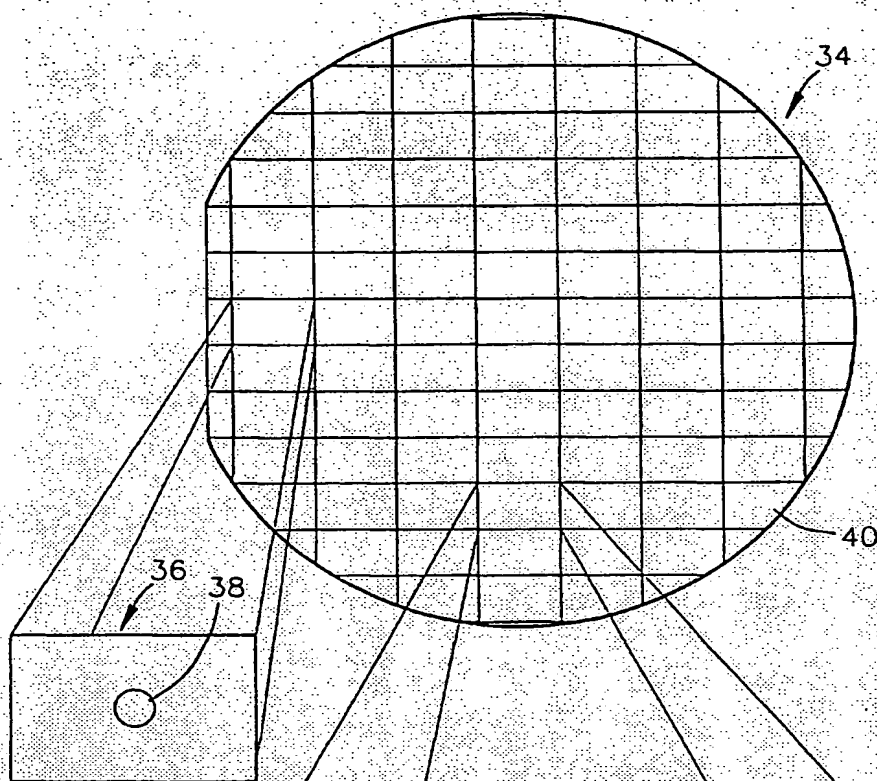


Fig. 1B

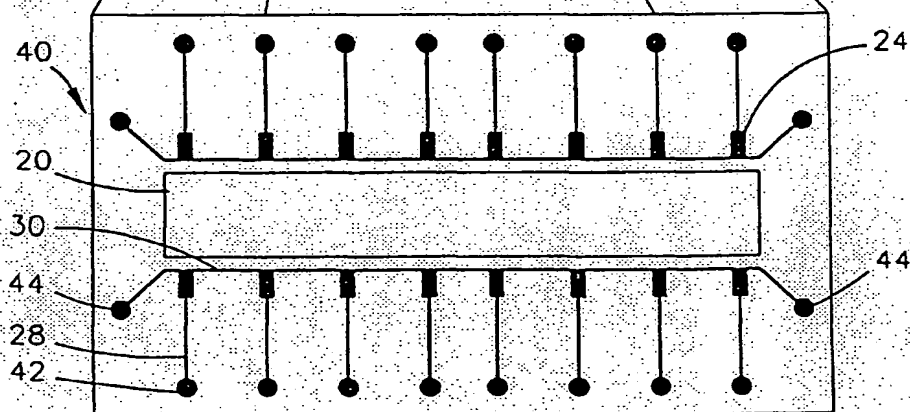
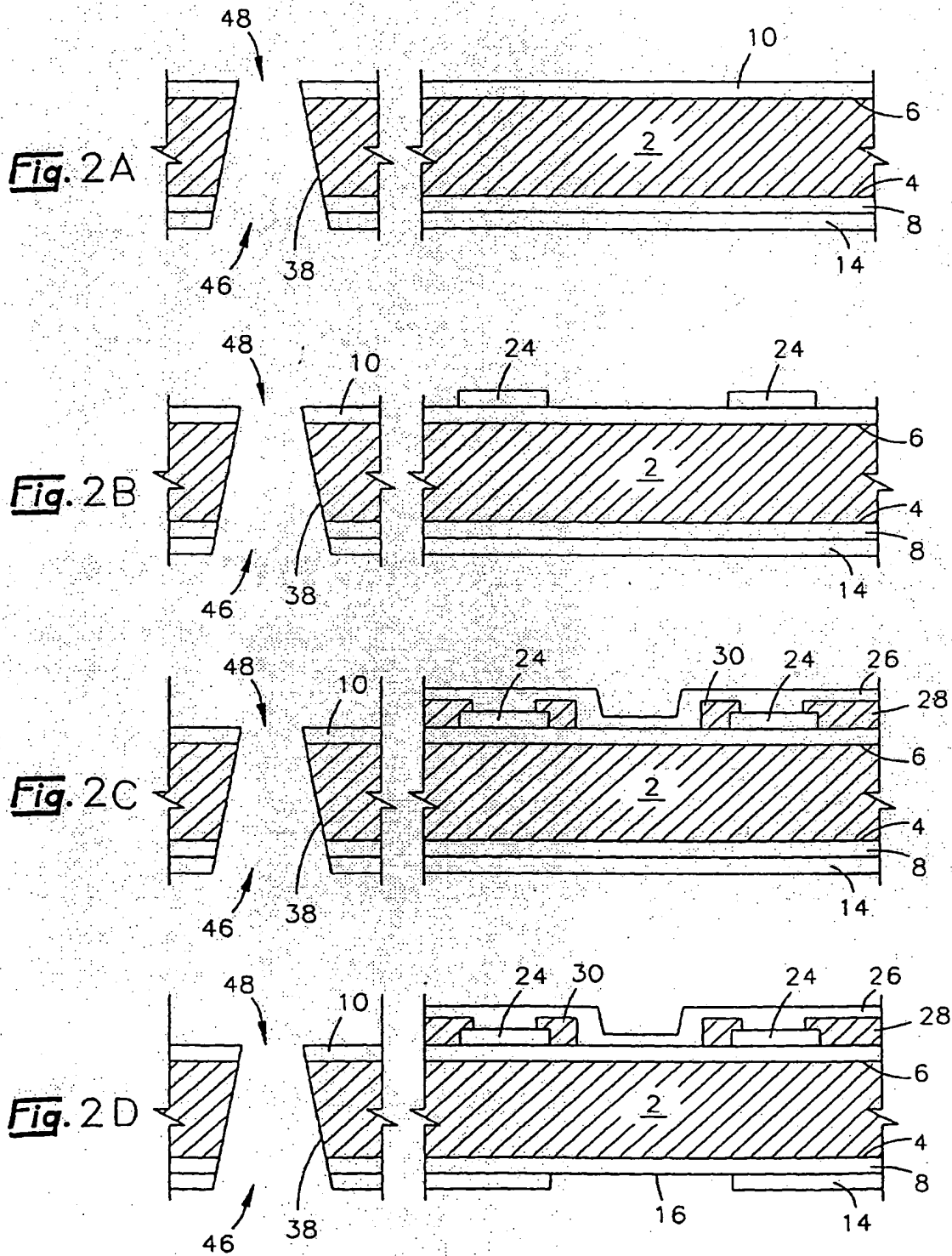
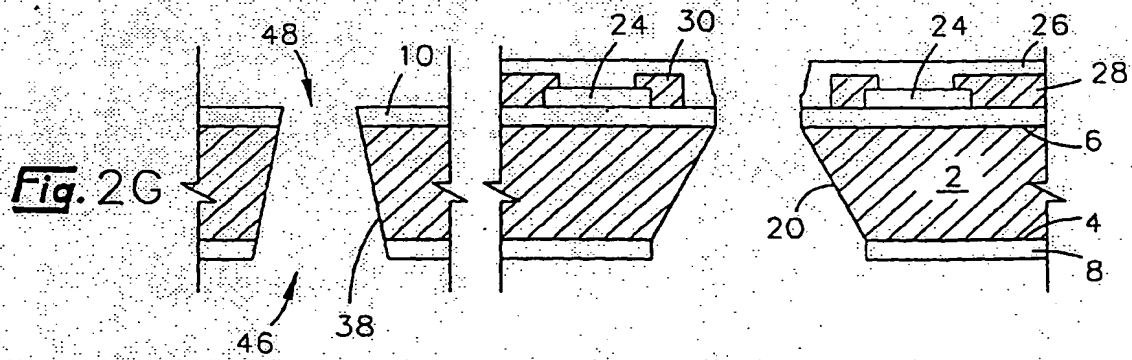
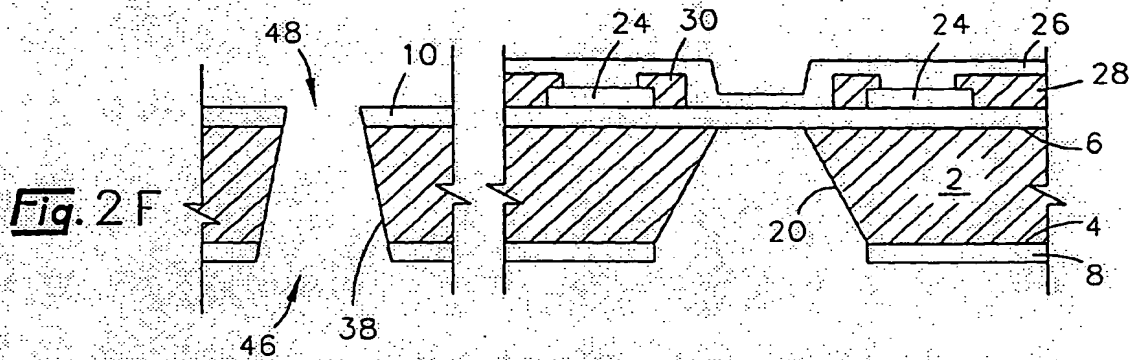
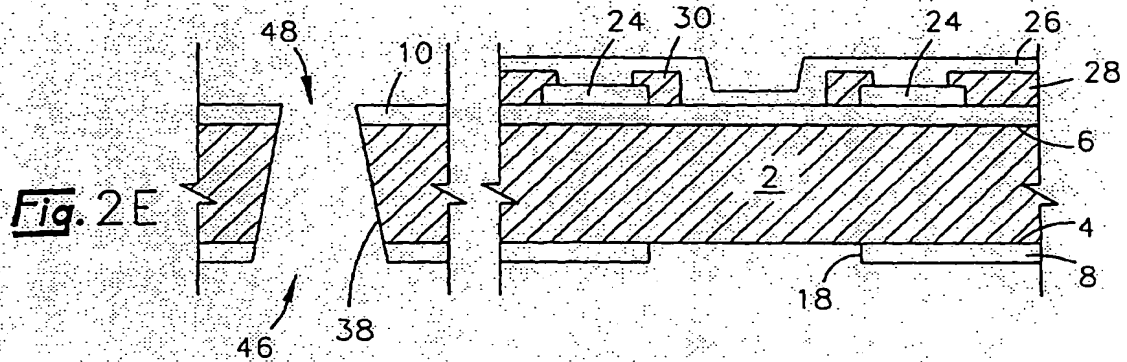


Fig. 1C



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